AUTOMATIC DEFECT DETECTION OF PRINTED CIRCUIT BOARD

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Abstract: Visual inspection of the printed circuit boards (PCB's) by human controllers is becoming impossible with the increasing complexity and miniaturization of the circuit boards. To achieve high reliability of the PCB's manufacturers are forced to develop new methods of inspection that will ensure inline control of every circuit board and separate those that does not fulfil the quality requirements.

Keywords: Image processing, PCB defect detection, Automated x-ray inspection

1. INTRODUCTION

Detection of defects during the manufacturing process of the printed circuit boards (PCBs) is a never-ending search that is driven by the desire to make the assembly process more efficient. Because of the great increase of demand of the electronic devices, printed circuit board (PCB) manufacturers have taken very important place. They are expected to deliver more circuit boards, cheaper with higher quality. Due to the world market of PCBs reached an estimated $60.2 billion in value in 2014 [1], a lot effort is put to improve the process of manufacturing. This paper focuses on the inspection part of the manufacturing process especially on the visual inspection using the x-ray and machine vision because by using these technologies, manufacturers can achieve high reliability and reduce repair costs.

The goal of the inspection is not to only find fatal defects such as breakout, bridges or missing conductor that will compromise the PCB performance during utilization, but also to find potential defects that can cause troubles in the longer time period such as over etching, under etching or voids in the Ball grid array (BGA).

Many of these problems can be addressed by automatic x-ray inspection since this method has several advantages over other means of inspecting. It is very fast in comparison with the in-circuit tests (ICT) and functional test (FT), it is very flexible because there is no need to make special fixture for each type of board and it can detect more types of defects than optical inspection using the visible light because AXI measures the how much light hot absorbed by the PCB so it can see through components which also brings a drawback in the form of the interface of the components on the multilayer boards in case of using the 2D capturing method instead of more advanced Computed Tomography that allows to pick particular layer that we want to inspect.

2. BGA VOID DETECTION

My bachelor's thesis covers detecting missing components, shifted components, void detection in the thermal paste of QFN package but in this paper I will cover just the BGA void detection. The most crucial part of the BGA void detection is the segmentation of the solder balls because solder balls are often interfered by other board components so the robust algorithm that is able to deal with various kinds of interference is crucial.

2.1. SOLDER BALL SEGMENTATION

In the first step we need to separate components, including the solder balls from the background. The most common method to separate background from the foreground is the thresholding. Because the 2D x-ray image of the PCB can be considered as the image with the bi-modal histogram we can use OTSU method to calculate the optimal threshold level. [2]

Afterwards we have to find all circles on the resulting image and decide if they are solder balls or not. The conventional circle detection algorithm is Hough transform, but in case of pictures with high resolution Hough transform becomes very slow so I have decided to find circles on the image using the boundary rectangles. This method is very easy and extremely fast even with the high resolution images. We just surround every foreground object on the image by the rectangle and if the rectangle has equal height and width, we can consider the object inside as a circle.

Image size [px]	Hough transform [sec]	Boundary rectangles [sec]
600x600	0.3137	0.0029
4000x4000	73.080	0.0572
2300x2300	13.689	0,0188

Table 1: Comparison of Hough transform and boundary rectangle methods

This method is prone to false detection such as vias that have also circular shape or some other components that have square shape so it is necessary to come up with the set of the conditions that will eliminate false detected solder balls. The detected circle has to meet three conditions to be marked as a solder ball. The first condition is that the whole circle have to be on the image, the second condition is that most of the pixels inside the circle have to be black, user can affect this parameter but by default it is set to 75% of the circle area have to be black. In the last step circles with too big or too small radiuses are also filtered out. The right radius is calculated by median of all detected radiuses.

At this point all of the detected circles are solder balls, but usually some of the solder balls were not detected. To find these solder balls we can take advantage of the regular grid of the BGA. To do it we calculate Delaunay triangulation from the centres of detected circles. [3] That will connect neighbourhood centres of solder balls with the lines that we rotate three times by 90 degrees. Than we check all these potential solder ball locations and use previously mentioned conditions to decide if there is solder ball or not.

2.2. VOID DETECTION INSIDE OF THE SOLDER BAL

The process of image processing of the void detection can be very tricky due to low contrast and possible interference with the components on the other side of the board. The images that I have available have low contrast and suffers from salt and pepper noise. So the fist step in the image processing is using the median filter that is very effective in suppression of the salt and pepper noise. The second step is to increase the contrast of the image. To enhance the contrast of the image the global contrast enhancement alone is not sufficient so I have decided to use the Contrast Limited Adaptive Histogram Equalization (CLAHE) that is improving the contrast in the smaller regions of the image.

After image enhancement we have to find the borders of the voids. Voids are typically circular bright spots on the image so to find their border we can use one of the many edge detection algorithms. I have implemented canny edge detector, difference of Gaussians (DoG) and Laplacian of Gaussian

(LoG) and got the best results with the LoG algorithm with the proper size of the filter. This edge detector usually detects also borders of noise so after the edge detection I use the morphological closing to get rid of the detected noise. Afterward I also check the circularity of the detected void because the typical void has circular shape so all shapes that are not circular are eliminated.

In the last step the area of all voids inside each circle is calculated and divided by the area of the solder ball to get the ratio between void and solder ball area.

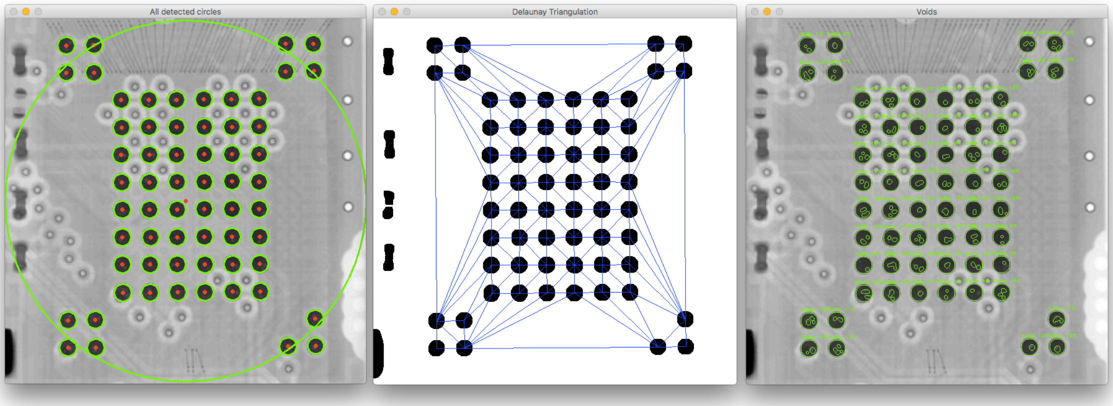

Figure 1: Example of the image processing steps

3. CONCLUSION

This paper presents a robust technique for segmentation of the solder balls from the x-ray image of the PCB. The program is able to find all solder balls even if the initial algorithm for searching the circle on the image fails and finds just a few solder balls from the BGA using the triangulation. The void detection algorithm is able to find even voids that in the solder balls with the low contrast that are barely visible with human eye. The only drawback of this contrast enhancement algorithm is that it might enhance also noise in some cases and cause false void detections so it is necessary to tune few parameters for each source of x-ray images.

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